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PATENT

IN THE U.S. PATENT AND TRADEMARK OFFICE

Applicant:	Neville Ernest LANGE	Conf. No.:	1710
Appl. No.:	10/631,822	Group:	3765
Filed:	August 1, 2003		
For:	IMPROVEMENTS IN AND RELATING TO GAS EDUCATORS AND GAS EDUCATOR FLOTATION SEPARATORS		

LETTER

Assistant Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

Date: January 6, 2004

Sir:

Under the provisions of 35 U.S.C. § 119 and 37 C.F.R. § 1.55(a), the applicant(s) hereby claim(s) the right of priority based on the following application(s):

Country	Application No.	Filed
BRITAIN	0217807.7	August 1, 2002

A certified copy of the above-noted application(s) is(are) attached hereto.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 25-0120 for any additional fee required under 37 C.F.R. §§ 1.16 or 1.17; particularly, extension of time fees.

Respectfully submitted,

YOUNG & THOMPSON

By ____________________

Robert J. Patch, #17,355
745 South 23rd Street, Suite 200
Arlington, Virginia 22202
(703) 521-2297

RJP/psf

Attachment

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INVESTOR IN PEOPLE

The Patent Office
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Newport
South Wales
NP10 8QQ

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

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Signed Stephen Hordley

Dated 30 September 2003

Patents Form 1/77

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01AUG02 E737689-4 D01559
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1.	Your reference	RRH/IRJ/AD/ASB.3
2.	Patent application number *(The Patent Office will fill in this part)*	0217807.7
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Axsia Serck Baker Limited Axsia House Waterwells Business Park Gloucester GL2 4AS
	Patents ADP number *(if you know it)*	7370455002
	If the applicant is a corporate body, give the country/state of its incorporation	United Kingdom
4.	Title of the invention	A Gas Eductor Induced Gas Floation Separator
5.	Name of your agent *(if you have one)* "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Wynne-Jones, Laine & James 22 Rodney Road Cheltenham Glos GL50 1JJ United Kingdom
	Patents ADP number *(if you know it)*	1792001

		Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	--		

		Number of earlier application	Date of filing *(day / month / year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	--	

8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	Yes

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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	–
Request for preliminary examination and search *(Patents Form 9/77)*	One
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11. I/We request the grant of a patent on the basis of this application.

Signature Wynne-Jones Laine & James   Date

Wynne-Jones, Laine & James   31st July 2002

12. Name and daytime telephone number of person to contact in the United Kingdom   Mr R Halstead   01242 515807

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A Gas Eductor Induced Gas Flotation Separator

The present invention relates to a gas eductor induced gas flotation separator.

In the oil and waste water industries a process known as flotation is commonly used to assist in the removal of oil and other contaminants from water. The principal of flotation is that bubbles of gas are introduced into or generated in a vessel containing a contaminated water, in which the bubbles will to a greater or lesser degree attach to the contaminants and drag them to the surface of the water, leaving the bulk of the water depleted of contaminants, and the upper layers of the water enriched of the contaminants. In subsequent discussion each volume of water to which gas bubbles are added to separate contaminants will be called a cell or flotation cell.

Flotation is usually operated as a continuous process where there is a continuous inflow of contaminated water into the cell and a continual outflow of contaminant enriched water drawn from the surface layers of the cell and a continual outflow of the contaminant depleted water drawn from the cell at a rate so as to maintain an essentially constant level in the vessel.

It is usual for the contaminants floated to the surface of the water to be retained in a froth which is either formed naturally when the contaminants are present at the higher concentrations found at the water surface, or with the assistance of chemicals which are added to the inflowing liquid. Buoyant contaminants, for example droplets of oil, may not need to be frothed to keep them at the surface.

The contaminants on the water surface are removed by a variety of means, the two most common being weirs set slightly below the water surface so that the contaminant enriched surface layer preferentially flows over them, or paddles which sweep the contaminant enriched surface layer over a weir which

is normally set slightly above the water surface. A number of designs of floating skimming devices are also made which have the advantage that they can tolerate a wider variation in operating liquid level than either of the aforementioned fixed weir methods can accommodate.

The gas bubbles which cause the flotation are commonly generated or introduced by two methods, called "dissolved gas flotation" and "induced gas flotation".

In dissolved gas flotation a flow of water, usually contaminant depleted water taken from the cell outlet, is contacted with the gas at an elevated pressure, so that gas in a quantity in excess of that which would saturate the water at the pressure in the flotation cell dissolves in the flow. The flow is then reintroduced into the cell with its pressure being reduced close to the point of its reintroduction into the cell. After the pressure reduction the flow is supersaturated with gas, and the excess gas comes out of solution in the form of bubbles. This method of bubble generation produces relatively small bubbles, typically 50 to 70 microns in diameter, which rise quite slowly and the cell has to be designed to have minimal turbulence and mixing, and low fluid velocities, so that the bubble rise is not inhibited. It is important that gas bubbles are evenly distributed through the contaminated water to maximise the quantity of the contaminant that is removed, but because turbulence and mixing is intentionally minimised in the cell this must be achieved by careful design of the contaminated water flow path and the way in which the flow containing the excess dissolved gas is reintroduced into the cell. In a properly designed cell the multitude of small bubbles are very effective in separating the contaminants and the minimal turbulence and mixing results in their being minimal mixing and hence contamination of the fluid through which the bubbles have passed by the

inlet fluid, so that a high efficiency of removal of the contaminants can be achieved in a single cell.

In induced gas flotation the gas is drawn into the water by a mechanical or hydraulic means, and the resulting processes are called mechanical induced gas flotation or hydraulic induced gas flotation respectively.

To provide the gas bubbles in mechanical induced gas flotation, a mixer is inserted into the cell and a vortex forms above it through which gas is drawn down to the impeller of the mixer. The gas is broken into bubbles and expelled from the mixer in a generally radial direction along with the water which the mixer also pumps. The bubbles are distributed through the fluid in the cell by the rapid circulation caused by the mixer.

To provide the gas bubbles in hydraulic induced gas flotation a flow of water is taken from the cell, usually contaminant depleted water taken from the cell outlet, pressurised by a pump and then returned into the cell through an eductor which draws gas into the flow. The cell usually has impingement plates or similar devices onto which the returning flow is directed to improve the distribution of the returning flow and the gas bubbles it contains. As with mechanical induced gas flotation, mixing is necessary to distribute the bubbles in the fluid in the cell. Mixing is caused by the momentum of the returning flow and because the bubbles are not uniformly distributed gas lift also occurs in the regions of high bubble concentration which causes further mixing or circulation.

Both means produce bubbles that are significantly larger than those produced by dissolved gas flotation, and both processes have significant mixing in the cell. For a given quantity of gas, increasing the bubble size reduces the efficiency of contaminant removal because it makes fewer bubbles which reside in the liquid for a shorter time due to their faster rise rate. The mixing and bubble size contribute to a cell contaminant removal efficiency which is therefore

much lower than is achieved in dissolved gas flotation. As a consequence induced gas flotation processes normally incorporate a number of cells (typically 4 to 6) operating in series to provide the necessary overall contaminant removal efficiency. Induced gas flotation processes however generally have higher specific throughputs (ratio of throughput to size) than dissolved gas flotation and can operate with warmer waters where the reduced gas solubility of water makes a dissolved gas flotation process less practical. Dissolved gas flotation is used in wastewater and drinking water treatment where very fine contaminants are agglomerated by chemical flocculants before entering the cell. Induced gas flotation is unsuitable for this application because the agglomerates are quite fragile and would be broken up by the mixing and turbulence in their cells.

In recent years another configuration of flotation process has become popular for applications in the offshore oil industry. It consists of a single flotation cell, generally a vertical cylindrical cell, with an eductor to provide the gas bubbles. The predominant application of these cells are to at least partially remove residual oil from produced water exiting liquid/liquid hydrocyclones before it is discharged into the sea. The large bubble size and degree of mixing inherent in induced gas flotation processes means that these cells do not have a high efficiency. As the amount of oil that is permitted to be present in produced water discharged to the sea is being reduced around the world, it would be desirable to improve the oil removal efficiency of these units.

In most hydraulic induced gas flotation process it would be of economic benefit to improve the contaminant removal efficiency.

Embodiments of this invention are intended to provide an improved eductor for hydraulic induced gas flotation which can produce finer bubbles than conventional eductors and which can distribute the gas bubbles within an

induced gas flotation cell with less mixing so that the efficiency of contaminant removal can be increased.

According to a first aspect of the present invention there is provided a gas eductor induced gas flotation separator including one or more gas introducing chambers for bringing a gas into contact with a contaminated liquid such as water by means of gas eductors, where contaminants in the liquid are floated to the surface of the liquid by attaching to gas bubbles emanating from each said eductor, each said eductor having a mixing and diffusing section substantially transverse to the axis of flow of the liquid entering the eductor, the eductor further including a channel section leading from the gas introducing chamber to the mixing and diffusion section, the channel section including:

an inlet portion adjacent to the aeration chamber;

an outlet portion adjacent to the mixing and diffusion section, and

an intermediate portion located between the inlet and outlet portions, the diameter of the intermediate portion being less than the diameter of the inlet portion, and the diameter of the outlet portion being greater than the diameter of the intermediate portion.

The inner wall of the channel section between the inlet portion and the intermediate portion may be substantially frusto conical in shape or it may be shaped substantially like an open end of a flared bell or the bell of a trumpet. The inner wall of the channel section between the intermediate portion and the outlet portion can be similarly shaped.

The mixing and diffusion section will typically be located at least partially in a space defined by an outer surface of the outlet portion and a body arranged substantially transverse to the flow of liquid through the eductor and adjacent the outlet portion. The body may be an impingement plate. The mixing and diffusing space can be generally annular. Thus, the bubbles emanating from the

eductor can emanate substantially radially through the space with respect to the flow of liquid through the eductor.

The impingement plate may be connected to the eductor by means of a plurality of studs, the studs possibly being fitted through a flange projecting from the channel section. In one embodiment, at least part of the outer surface of the outlet portion may be cut away so that the distance between the outlet portion and the impingement plate may be varied. Alternatively or additionally, at least part of the surface of the impingement plate facing the outlet portion may be cut away in a similar manner. The distance may generally increase with increasing radial distance from the point on the impingement plate where the jet is directed.

According to a second aspect of the present invention there is provided apparatus such as an eductor for mixing a gas with a liquid and diffusing the mixture, the apparatus including:

one or more gas introducing chambers for bringing a gas into contact with a liquid;

a mixing and diffusing section substantially transverse to the axis of flow of the liquid entering the eductor, and

a channel section leading from the gas introducing chamber to the mixing and diffusion section, the channel section including:

an inlet portion;

an outlet portion adjacent to the mixing and diffusion section, and

an intermediate portion located between the inlet and outlet portions, the diameter of the intermediate portion being less than the diameter of the inlet portion, and the diameter of the outlet portion being greater than the diameter of the intermediate portion.

The eductor may further include a nozzle component for producing a jet directed generally towards a said gas introducing chamber.

According to a third aspect of the present invention there is provided apparatus such as an eductor for mixing a gas with a liquid and diffusing the mixture, the apparatus including:

a nozzle for receiving a flow of liquid entering the eductor and producing a jet;

one or more gas introducing chambers for bringing a gas into contact with the jet of liquid;

a mixing and diffusing section being substantially transverse to the axis of the liquid flow and being defined between an outlet portion of the eductor and a body spaced apart from the outlet portion,

wherein the mixing and diffusing section is generally annular and has an outer diameter up to 15 times greater than the diameter of the jet issuing from the nozzle.

A body may be arranged substantially transverse to the flow of liquid through the apparatus. The body may be a substantially flat impingement plate. The minimum diameter of the outlet portion where it becomes substantially parallel to the impingement plate is preferably as small as possible, whilst still allowing room for gas to enter the mixing and diffusing section from the gas introducing space.

The minimum diameter of the outlet portion where it becomes substantially parallel to the impingement plate can be less than 2 times the diameter of the jet.

The distance between the eductor outlet and the impingement plate may be between 1.5 and 6 times the depth of the liquid at the periphery of a generally circular area of the plate substantially equal in diameter to the minimum diameter of the outlet portion where it becomes substantially parallel to the impingement plate. The depth of the liquid at the periphery of the generally

circular area may be calculated as: (diameter of jet)^2/(4 x d1), where d1 is the minimum diameter of the outlet portion where it becomes substantially parallel to the impingement plate.

Whilst the invention has been described above, it extends to any inventive combination of the features set out above or in the following description.

The invention may be performed in various ways, and, by way of example only, embodiments thereof will now be described, reference being made to the accompanying drawings, in which:-

Figure 1 is a cross-section through a conventional eductor;

Figure 2 is a cross-section through an eductor according to a first embodiment of the present invention;

Figure 3 is a view similar to that of Figure 2 but highlighting possible modifications to the eductor;

Figure 4 is a cross-section through a further embodiment;

Figures 5 to 8 are graphs illustrating the results of testing one embodiment;

Figure 9 is a cross-section through the eductor being tested to produce the results shown in the graphs;

Figure 10 is a cross-section through a prior art eductor, and

Figures 11 and 12 are graphs showing the bubble sizes produced by the eductors of Figures 9 and 10, respectively.

A conventional eductor is shown Figure 1. The conventional eductor has an inlet port for motive water 1, an inlet port for gas 2, and an outlet port 3, for the combined flow. Once inside the body of the eductor the motive water passes through a converging nozzle 4, to produce a jet of water 5. The jet of water 5, passes through a space 6 where the jet is surrounded by the gas which

has entered the body of the eductor through the gas inlet port 2. The jet then enters a substantially cylindrical section 10, termed the mixing section. In the mixing section the motive water mixes with the gas so that a fairly uniform mixture enters the diffuser 11 at a fairly uniform velocity. The inlet end of the mixing section normally has a radius 7 or some other profile designed to reduce the resistance to the flow of gas entering the mixing section. The diffuser is a conical section which is a normally straight walled, which matches the diameter of the mixing section at its small end 9 and the diameter of the outlet 13 at its large end. The diffuser typically has an included angle of 6^{o} to 7^{o}, and may have a diameter at its big end that is 2 to 3 times of the diameter at its small end which would give a ratio of the areas of the big end to the small end of 4:1 to 9:1. The method by which the educator works is as follows:

i) The motive water is converted into a high velocity jet in the converging nozzle 4, turning part of its pressure energy into kinetic energy ie velocity.

ii) The motive water and the gas mix in the mixing section. The velocity of the mixture exiting the mixing section follows the principle of conserving the momentum of the two streams entering the mixing section.

iii) The mixture is decelerated in the diffuser, converting its kenetic energy ie velocity, to pressure. The ratio of the cross sectional areas at the inlet and outlet end of the diffuser set how much the flow reduces in velocity and hence how much pressure it can regain.

Bernoulli's theorem can be used to calculate the theoretical maximum conversion of pressure to velocity and visa versa occurring in the motive water nozzle and the diffuser provided that suitable allowances are made for frictional losses. Due to the high velocities in the eductor losses of energy can be rapid if the eductor is not of optimum design. ESDU International publish verified design methods for eductors which detail the important design features.

An improved eductor is shown in Figure 2. The improved eductor has an inlet port 101 for motive water leading to a converging nozzle 104. The eductor also has an inlet port 102 for gas, the two inlets being arranged substantially perpendicular to each other. The two inlets lead to a space 106 within the body of the eductor. The upper portion of the space 106 is generally annular, with the outer surface of the nozzle 104 giving the central aperture of the annular shape a frusto conical profile. The lower part of the space 106 curves downwards to form an opening leading to a generally annular space 103. The curved wall 107 leading to the opening is designed to reduce the resistance to the flow of gas which is drawn into the liquid.

The annular space 103 is formed between the end face 110 of the eductor body 100 and an adjacent flat plate 99. It will be understood that although flat impingement plates are shown in the embodiments described herein, the invention should not be so limited. For example, the jet of liquid could be directed generally towards another body such as the bottom of a flat bottomed vessel or a block of material. The space 103 extends from a diameter d1 where the end face 110 first becomes parallel to the flat surface to a diameter d2 equal to the diameter of the eductor body 100. Where the eductor body does not have a cylindrical exterior, diameter d2 would be taken as the as the smallest diameter greater than diameter d1 where the gap between the end face of the eductor and the surface is greater than 6 times the liquid film thickness at diameter d1 and the end face of the eductor body first makes an angle to the surface which is larger than 20°.

In use, the motive water passes from the inlet 101 through the nozzle 104 to produce a jet of water 105. The jet passes through the space 106 where the jet is surrounded by the gas which has entered the body of the eductor through the gas inlet port 102. The jet then passes through the opening in the end of the

eductor body, to impinge on the flat surface 99, the axis of the jet being substantially normal to the flat surface. The jet of water then spreads out substantially radially on the flat surface from its point of impingement, and passes into the annular space 103. In its passage through the annular space 103, the water entrains gas so that a mixture of water and gas bubbles exit from the eductor body.

In comparison to the conventional eductor, the improved eductor lacks a clearly defined mixing section and diffusing section within the eductor body. The function which is defined as mixing in the conventional eductor where the flow is axial, could be considered to occur in the improved eductor where the flow is radial, within some or all of the annular space 103. The function which is defined as diffusing in the conventional eductor, could be considered to occur in that portion of the annular space beyond the radius at which mixing is considered to occur. It is likely, however, that there is an overlap in the regions where these functions are occurring. This may be detrimental to achieving optimal performance of either function, so that the improved eductor may not draw as much gas as a conventional eductor when operated at the same pressures and motive water flow.

Figure 3 illustrates how the profile and dimensions of the end face 110 of the improved eductor may be modified to provide a greater or lesser opportunity for the functions of mixing and diffusing to occur. Increasing the diameter of the endface 110 to a diameter d3 greater than diameter d2 will increase the cross sectional area through which the flow exits from the annular space between the endface 110 and the flat plate 99.

Although specific dimensions are given for an embodiment of Figure 9 described below, the inventor has found that the following dimensions can result in eductors that can produce finer bubbles than conventional eductors and which

can distribute the gas bubbles within an induced gas flotation cell with less mixing so that the efficiency of contaminant removal can be increased. The diameter d2 can be up to 15 times greater than the diameter of the jet issuing from the nozzle104. The diameter d1 is preferably as small as possible, whilst still allowing room for gas to enter the annular area from the gas introducing space 106 and d1 can be less than two times the diameter of the jet issuing from the nozzle 104. The thickness of the annular space 103 may be between 1.5 and 6 times the thickness/depth of the radially spreading water film at the periphery of a generally circular area on the plate 99 having a diameter d1. The depth of the film of water at the periphery may be calculated as (diameter of jet)^2/(4 x d1).

Providing an angle on the endface, or the flat plate 99 or both so that the gap between them is greater at the outer edge of the annular space than at the inner edge of the annular space also increases the cross sectional area through which the flow exits from the annular space. Such angles can be achieved by cutting away portions of the endface and flat plate as shown by the broken lines between g1 and g2. Both modifications also increase the volume of the annular space and they may be used in combination. Increasing the cross sectional area through which the flow exits from the annular space in the radial eductor reduces its velocity and is analogous to providing a diffuser with a greater area ratio on a conventional eductor. It is to be noted however that the diffuser of an improved eductor may not be particularly efficient, in that it may have flow separation from one or both walls, but that this does not detract from the invention.

The embodiment of Figure 4 shows an embodiment of an eductor 400 having an inlet 401 formed of a substantially cylindrical piece. The inlet cylinder 401 is fitted into one opening of a threaded pipe tee 405. At the lower end of the

inlet cylinder 401 there is fitted a nozzle piece 404. An o-ring 411 is fitted within an annular groove around the outside of the nozzle piece 404 and is in contact with the inner surface of the inlet cylinder 401 to form a seal between them to prevent motive water bypassing the nozzle.

The opening at the branch of the threaded pipe tee 405 is used as an inlet port 402 for gas. Fitted to the opening of the threaded pipe tee 405 across its run from the opening containing the inlet cylinder 401 is an eductor component 407. The central body of threaded pipe tee 405 includes a space 406 where liquid passing through the nozzle 404 and gas passing through the port 402 can come into contact with each other. The eductor component 407 is shaped so that it forms a substantially frusto conical funnel leading to the space 406. Below the narrow end of the funnel, the side walls of the component 407 flare outwardly to form the substantially flat, perpendicular end face 410 of the eductor component.

The eductor component 407 also includes an outer flange 412 near its end face. The flange 412 includes apertures through which machined studs 413 are fitted to attach a circular impingement plate 414 to the bottom of the separator 400. A space 403 is present between the end face 410 of the eductor component 407 and the adjacent surface of the impingement plate 414. As described for the embodiment of Figure 2 above, the space 403 can be used to produce radially emanating bubbles.

In comparison to the conventional eductor where the outlet flow of gas and water exits in an axial direction, the outlet flow of gas and water exits from the improved eductor in a substantially radial direction. This provides inherently in the eductor a means of directing the gas and water mixture into the contaminated water to effect distribution of the gas bubbles. As described above, the geometry of the end face of the improved eductor can be modified to

vary the velocity of the outlet flow so that the distribution can be optimised for a particular cell geometry.

It is a first common practise where a conventional eductor is used in a hydraulic induced gas flotation cell to position the eductor so that its outlet points vertically downwards onto a horizontal impingement plate so that the flow exiting axially from the eductor hits the plate and is deflected radially outward. Placing the impingement plate close to the outlet of the eductor produces a higher radial velocity which generates a greater backpressure on the outlet of the eductor, but the higher velocity allows the gas bubbles to be distributed into the surrounding water to an greater radial distance from the eductor. To match the radial velocity that the improved eductor produces, a conventional eductor would need its impingement plate to be positioned away from the eductor outlet at a distance of approximately 0.05 to 0.15 times the diameter of the outlet. In this position most of the pressure that is recovered in the diffuser section of the conventional eductor is used to accelerate the flow to pass through the small gap between the end of the eductor and the impingement plate.

A second common practice where a conventional eductor is used in a hydraulic induced gas flotation cell to position the eductor in pipework which may be external to the cell, and pipe the outlet flow of gas and water into a distributor manifold within the cell. This construction is used so that the eductor can be accessed for maintenance or inspection without having to enter the cell. It may also be possible to position the eductor above the normal liquid level in the cell so that the cell does not need to be drained to remove the eductor.

When operated in a hydraulic induced gas flotation cell, it was found that the improved eductor produced a smaller bubble size than a conventional eductor mounted as described in the first common practise. In fresh water the reduction in bubble size was found to be greater than in saline water. The exact

mechanism for this is not certain but since it is known that gas bubble coalescence is slower in saline waters, it is thought to be due to the improved eductor more rapidly dispersing the gas bubbles so that they are unable to coalesce into larger bubbles. If the operation of the conventional eductor in this service is examined it will be seen that after the bubbles are generated in the mixing section they must pass through the diffuser and then turn through an angle of 90° on the impingement plate before being dispersed into the bulk of the water in the cell. The probability of gas bubble collision, which is a precursor to coalescence remains high until the bubbles are well dispersed into the bulk liquid. In the improved eductor the gas bubbles are generated in a water flow which is already radial, and the flow is diffused only to the required velocity for distribution before being introduced to the bulk of the liquid, which results in the gas bubbles having a shorter residence time in the eductor. In the conventional eductor the residence time between the end of the mixing section and where the radial flow was introduced into the bulk of the water was of the order of 0.025 seconds, in the improved eductor the time was of the order of 0.002 seconds. The shorter residence time in the improved eductor can mean that the gas bubbles are unable to coalesce into larger bubbles and therefore remain relatively small in size. In the second common practise described, it is clear that the residence time is further extended beyond that of the first common practise because the mixture of gas and water exiting the eductor additionally flows some distance in a pipe before being dispersed in the liquid in the cell. The second common practise is also found to produce a larger bubble size than the improved eductor.

Figures 5 to 8 are graphs showing the test results of an improved eductor 900 shown in Figure 9. The diameter of the aperture at the lower end of the nozzle 904 through which the jet is produced is 19mm. The distance (defining

the mixing and diffusing space 903) between the end face 910 of the eductor component 907 and the impingement plate 914 is 4mm. The distance between the lower end of the nozzle 904 and the end face 910 is 107mm.

The angle between the vertical and the side wall of the frusto conical upper inlet portion 907A of the eductor component 407 is 16°. An intermediate portion 907B of the component 407 where the side walls are substantially vertical has a length of 10mm. The minimum radius of the lower flared outlet portion 907C is 10mm. The minimum diameter where the end face 910 first becomes parallel to the flat surface 914 is 60mm. The diameter of the base of the eductor component 907 is 90mm.

For the results of Figures 5 to 7, the eductor 900 was tested at depths of 2068, 1399, 587 and 3223 millimetres. Referring first to Figure 5, the Y-axis of the graph represents the maximum vacuum (in barg) at the gas inlet 102/402 and the X-axis represents the motive flow of the water (in m^3/h) entering through the liquid inlet 101/401.

In the graph of Figure 6, the Y-axis represents the pressure drop (in barg) over the eductor nozzle 104/404 and the X-axis represents the motive water flow (in m^3/h) through the chamber.

The Y-axis of the graph of Figure 7 represents the entrained gas flow (i.e. the bubbles emanating from the diffusing and mixing section 103/403) in m^3/h, whilst its X-axis represents the motive water flow (in m^3/h) at the liquid inlet 101/401.

The Y-axis of the graph of Figure 8 also represents the entrained gas flow in m^3/h. The X-axis of the graph represents the vacuum (in barg) at the gas inlet. The results shown were taken from an eductor at a depth of 1403mm and having a motive water flow of 36 m^3/h.

Figure 10 shows the prior art eductor known as a Mazzei 2081-A at 1000 with an impingement plate 1002 located 8 mm away from its base so that the mixture exiting the eductor is given a substantial radial velocity.

Figures 11 and 12 illustrate the bubble sizes produced by the eductors of Figures 9 and 10, respectively. Both eductors were tested at a depth of 3220 mm. The improved eductor 900 was testing with motive water flows of 30 m^3/h, 25 m^3/h and 20 m^3/h. The prior art eductor 1000 was tested with motive water flows of 22.75 m^3/h and 19 m^3/h. The X-axes of the graphs represent the air volume fraction and the Y-axes represent the Backcalculated Stokes Bubble diameter in microns.

The smaller bubbles and improved distribution of bubbles that can be produced by embodiments of the invention can be of use in other processes other than separation of contaminants where mass transfer or a chemical reaction takes place between a gas and a liquid.

CLAIMS

1. A gas eductor induced gas flotation separator including one or more gas introducing chambers for bringing a gas into contact with a contaminated liquid such as water by means of gas eductors, where contaminants in the liquid are floated to the surface of the liquid by attaching to gas bubbles emanating from each said eductor, each said eductor having a mixing and diffusing section substantially transverse to the axis of flow of the liquid entering the eductor, the eductor further including a channel section leading from the gas introducing chamber to the mixing and diffusion section, the channel section including:

an inlet portion adjacent to the gas introducing chamber;

an outlet portion adjacent to the mixing and diffusion section, and

an intermediate portion located between the inlet and outlet portions, the diameter of the intermediate portion being less than the diameter of the inlet portion, and the diameter of the outlet portion being greater than the diameter of the intermediate portion.

2. A separator according to Claim 1, wherein the inner wall of the channel section between the inlet portion and the intermediate portion is substantially frusto conical in shape.

3. A separator according to Claim 1, wherein the inner wall of the channel section between the inlet portion and the intermediate portion is shaped substantially like an open end of a flared bell.

4. A separator according to any one of Claims 1 to 3, wherein the inner wall of the channel section between the intermediate portion and the outlet portion is substantially frusto conical in shape.

5. A separator according to any one of Claims 1 to 3, wherein the inner wall of the channel section between the intermediate portion and the outlet portion is shaped substantially like an open end of a flared bell.

6. A separator according to any one of the preceding Claims, wherein the mixing and diffusion section is located at least partially in a space defined by an outer surface of the outlet portion and an impingement plate fitted substantially transverse to the flow of liquid entering the eductor and adjacent the outlet portion.

7. A separator according to Claim 6, wherein the mixing and diffusing space is generally annular.

8. A separator according to Claim 6 or 7, wherein the impingement plate is fitted and spaced apart from the separator by a plurality of studs.

9. A separator according to Claim 8, wherein the studs are fitted through a flange projecting from the channel section.

10. A separator according to any one of Claims 6 to 9, wherein at least part of the outer surface of the outlet portion is cut away so that the distance between the outlet portion and the impingement plate is varied.

11. A separator according to any one of Claims 6 to 10, wherein at least part of the surface of the impingement plate facing the outlet portion is cut away so that the distance between the outlet portion and the impingement plate is varied.

12. A separator according to Claim 10 or 11, wherein the distance between the outlet portion and the impingement plate generally increases with increasing radial distance from the point on the impingement plate where the jet is directed.

13. Apparatus such as an eductor for mixing a gas with a liquid and diffusing the mixture in the form of bubbles, the apparatus including:

one or more gas introducing chambers for bringing a gas into contact with a contaminated liquid such as water;

a mixing and diffusing section substantially transverse to the axis of flow of the liquid entering the eductor, and

a channel section leading from the gas introducing chamber to the mixing and diffusion section, the channel section including:

an inlet portion;

an outlet portion adjacent to the mixing and diffusion section, and

an intermediate portion located between the inlet and outlet portions, the diameter of the intermediate portion being less than the diameter of the inlet portion, and the diameter of the outlet portion being greater than the diameter of the intermediate portion.

14. Apparatus according to Claim 13, wherein the mixing and diffusing section is located at least partially in a space defined by an outer surface of the outlet portion and an impingement plate fitted substantially transverse to the flow of liquid through the eductor and adjacent the outlet portion.

15. Apparatus according to Claim 13 or 14, further including a nozzle for receiving a flow of liquid entering the eductor and producing a jet,

wherein the mixing and diffusing section is generally annular and has an outer diameter up to 15 times greater than the diameter of the jet issuing from the nozzle.

16. Apparatus according to Claim 14, wherein the minimum diameter of the outlet portion where it becomes substantially parallel to the impingement plate is less than 2 times the diameter of the jet.

17. Apparatus according to Claim 16, wherein the distance between the eductor outlet and the impingement plate is between 1.5 and 6 times the depth of the liquid at the periphery of a generally circular area of the plate substantially equal in diameter to the minimum diameter of the outlet portion where it becomes substantially parallel to the impingement plate.

18. Apparatus according to Claim 17, wherein the depth of the liquid at the periphery of the generally circular area is calculated as: (diameter of jet)^2/(4 x d1), where d1 is the minimum diameter of the outlet portion where it becomes substantially parallel to the impingement plate.

19. Apparatus such as an eductor for mixing a gas with a liquid and diffusing the mixture in the form of bubbles, the apparatus including:

a nozzle for receiving a flow of liquid entering the eductor and producing a jet;

one or more gas introducing chambers for bringing a gas into contact with the jet of liquid;

a mixing and diffusing section being substantially transverse to the axis of the liquid flow and being defined between an outlet portion of the eductor and a body spaced apart from the outlet portion,

wherein the mixing and diffusing section is generally annular has an outer diameter up to 15 times greater than the diameter of the jet issuing from the nozzle.

20. Apparatus according to Claim 19, wherein the minimum diameter of the outlet portion where it becomes substantially parallel to the impingement plate is less than 2 times the diameter of the jet.

21. Apparatus according to Claim 19 or 20, wherein the body includes an impingement plate and the distance between the eductor outlet and the impingement plate is between 1.5 and 6 times the depth of the liquid at the periphery of a generally circular area of the plate substantially equal in diameter to the minimum diameter of the outlet portion where it becomes substantially parallel to the impingement plate.

22. Apparatus according to Claim 21, wherein the depth of the liquid on the generally circular area is calculated as: (diameter of jet)^2/(4 x d1), where d1 is

the minimum diameter of the outlet portion where it becomes substantially parallel to the impingement plate.

1/8

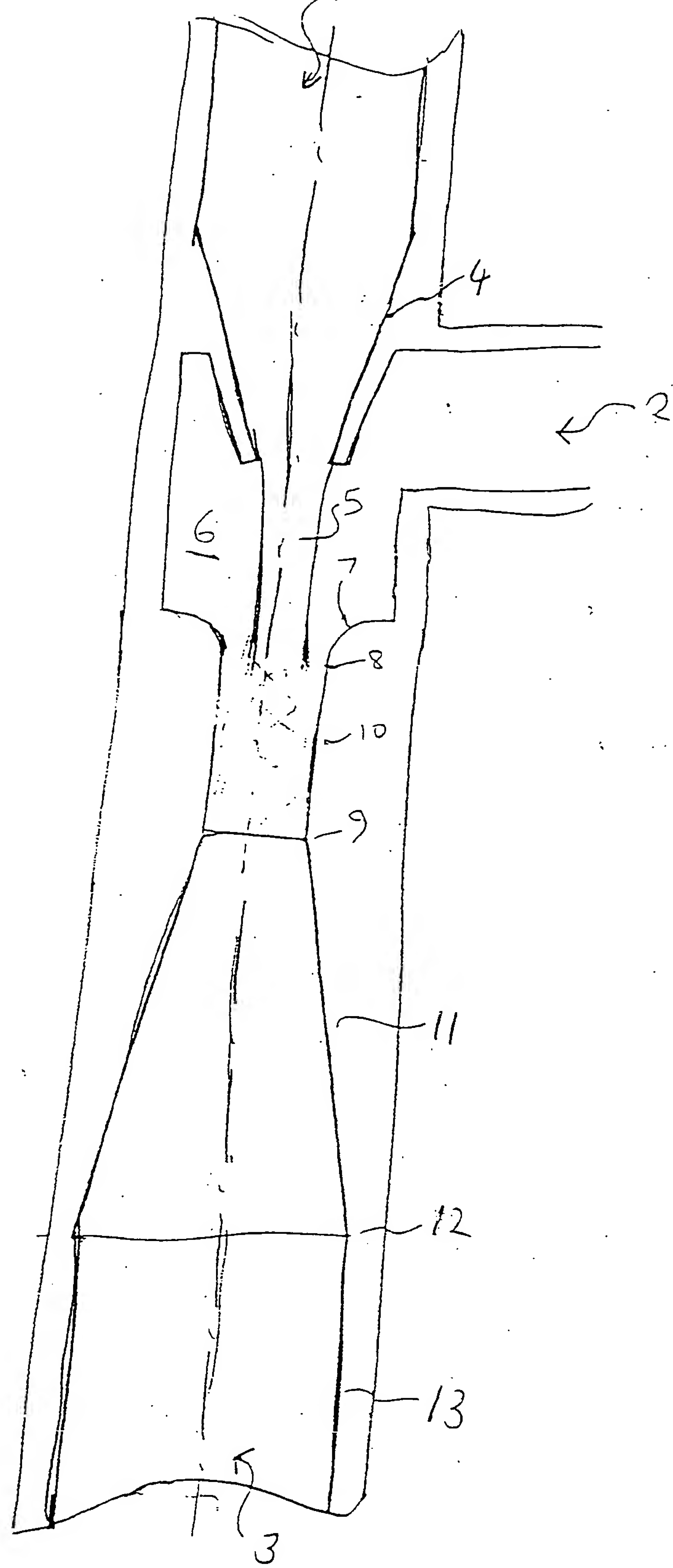

FIG. 1

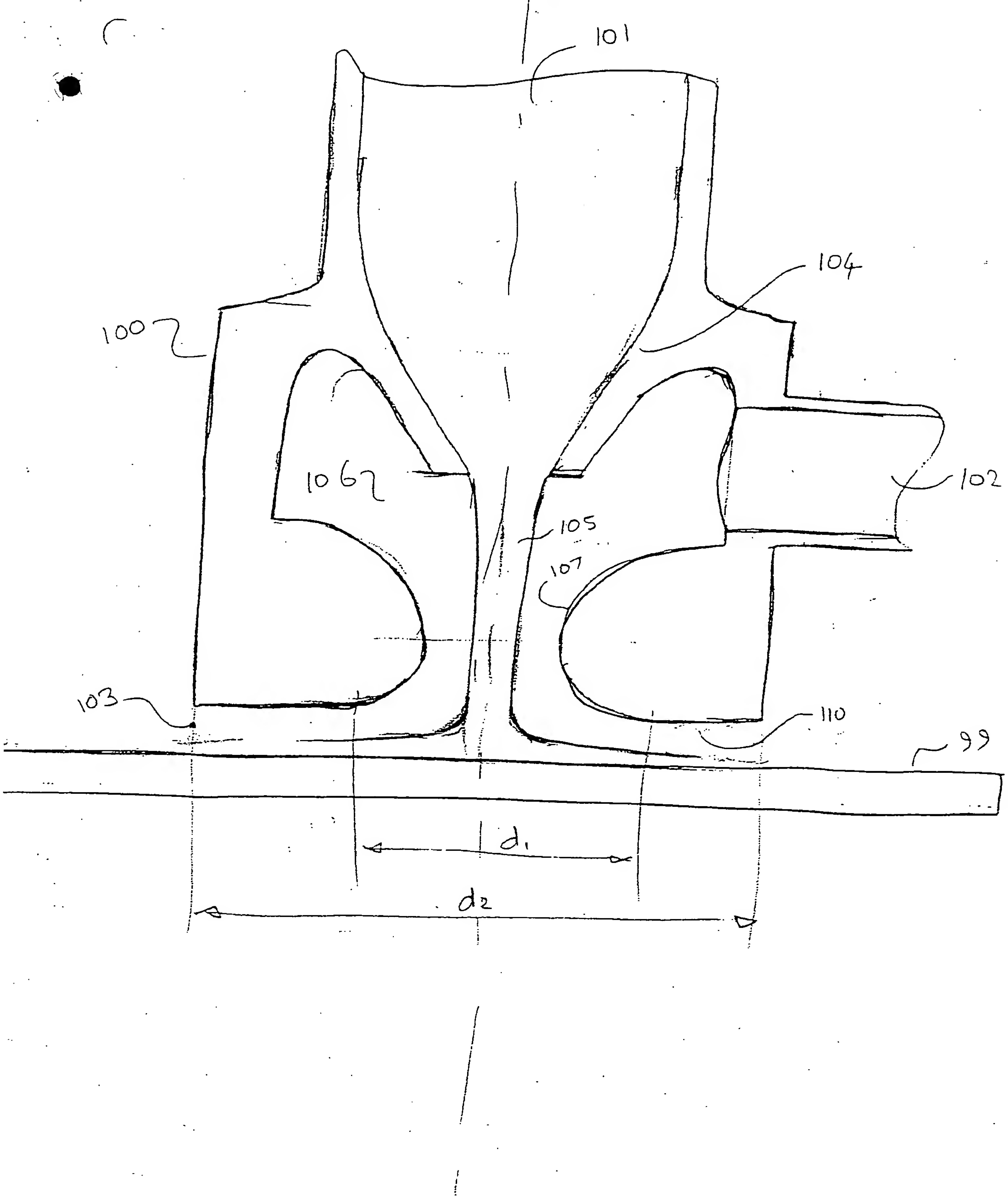

FIG. 2

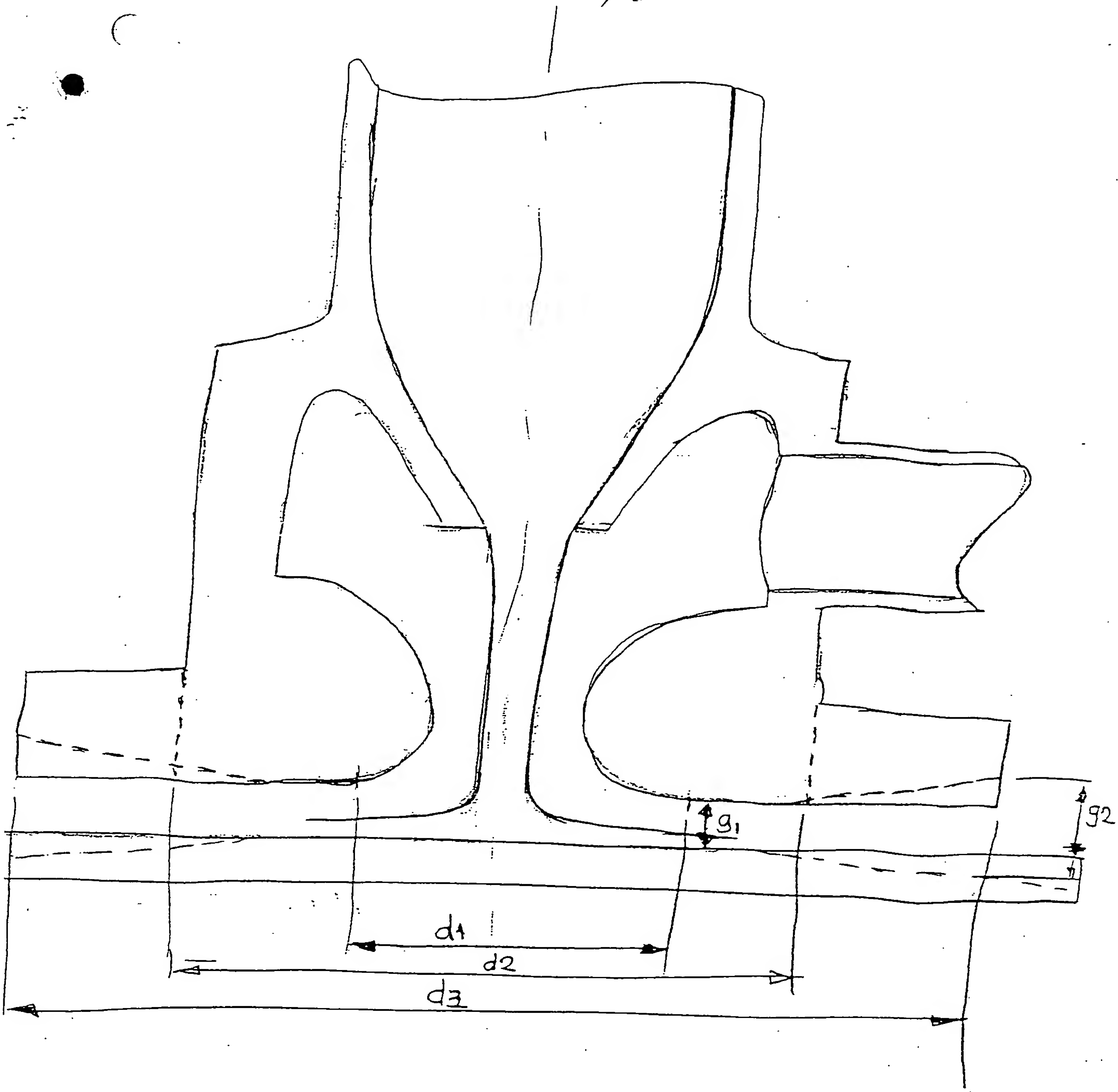

FIG 3

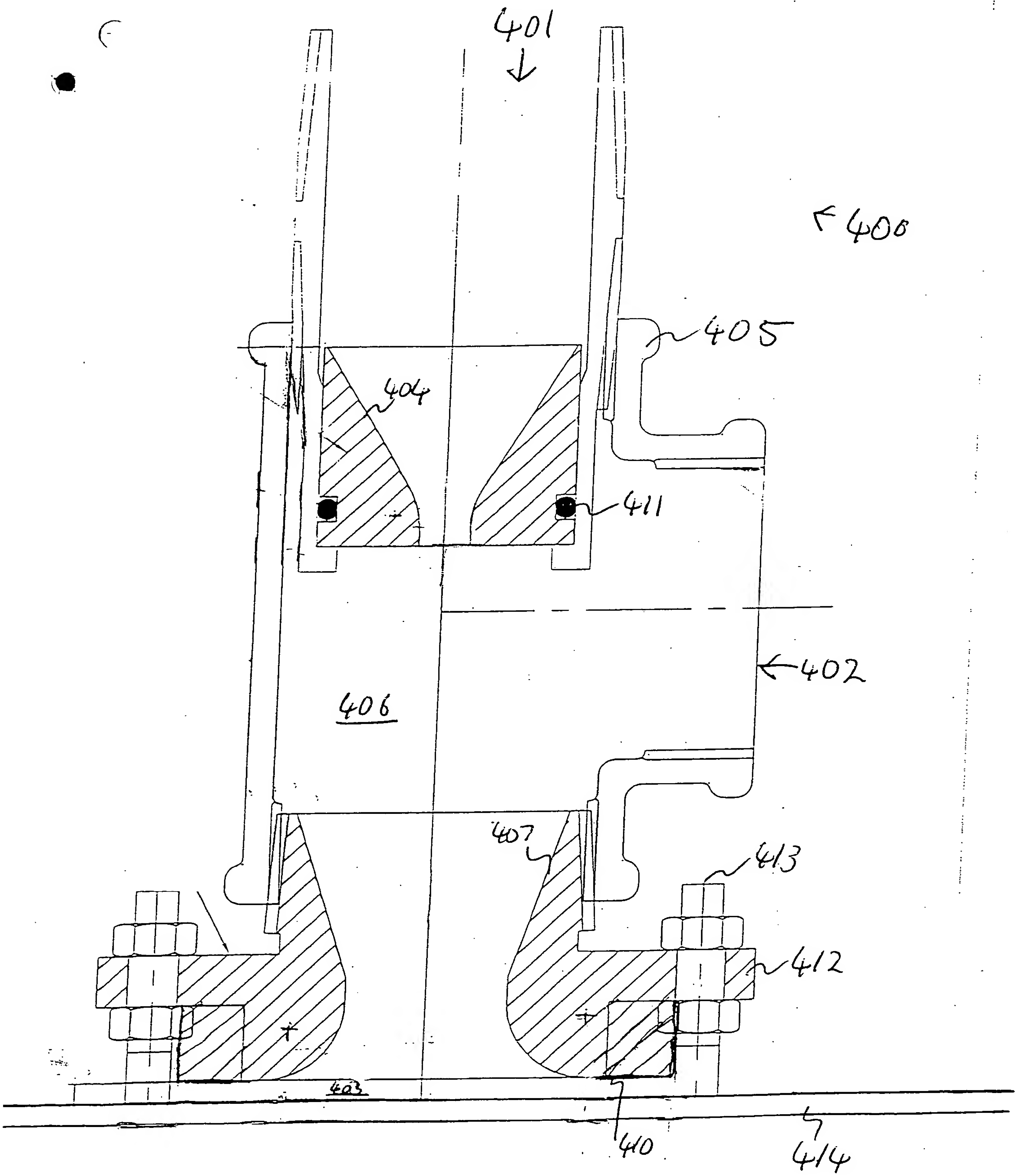

FIG. 4

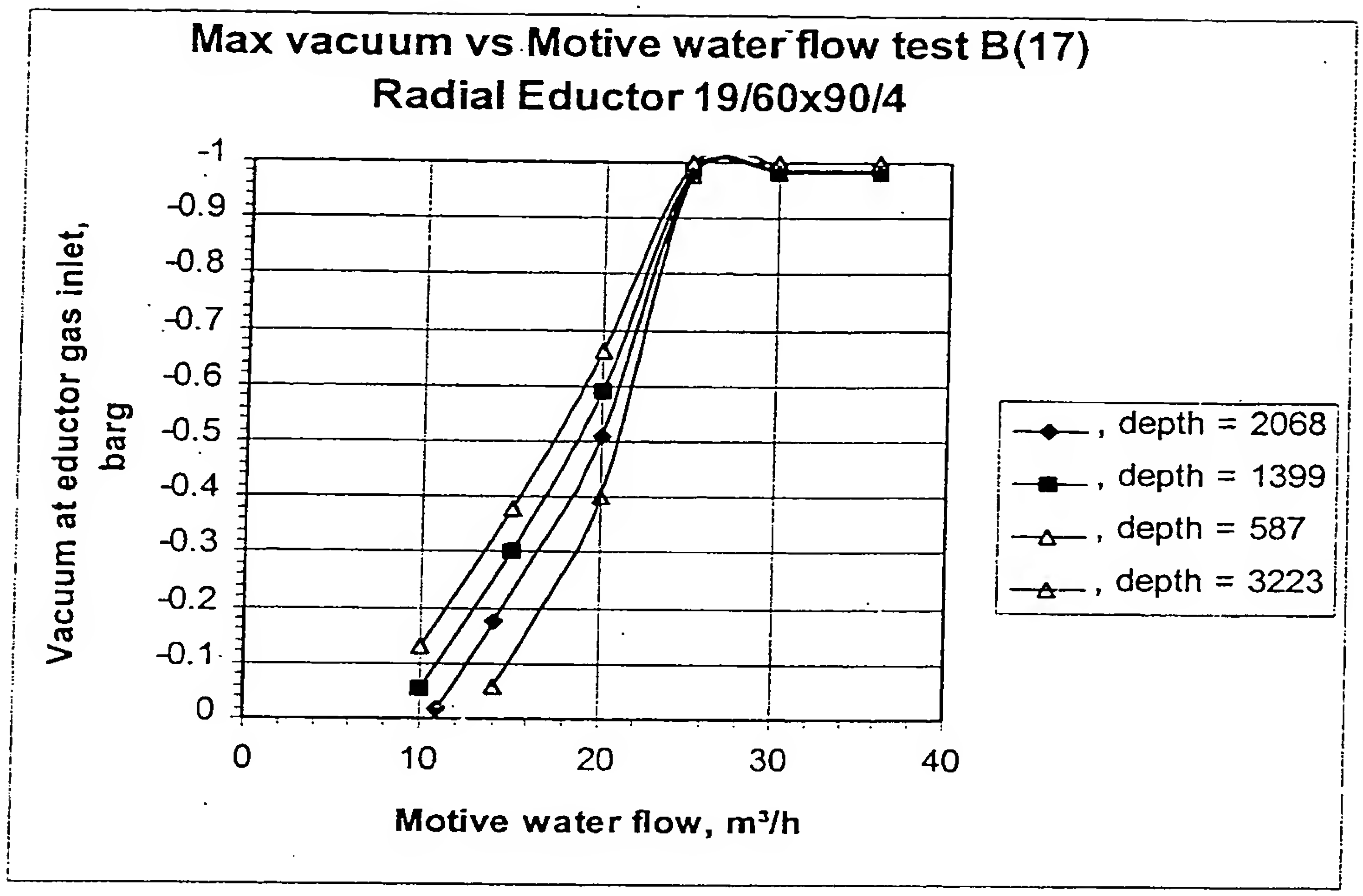
Max vacuum vs Motive water flow test B(17)
Radial Eductor 19/60x90/4
Vacuum at eductor gas inlet, barg
-1
-0.9
-0.8
-0.7
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0
10
20
30
40
Motive water flow, m³/h
, depth = 2068
, depth = 1399
, depth = 587
, depth = 3223

FIG. 5

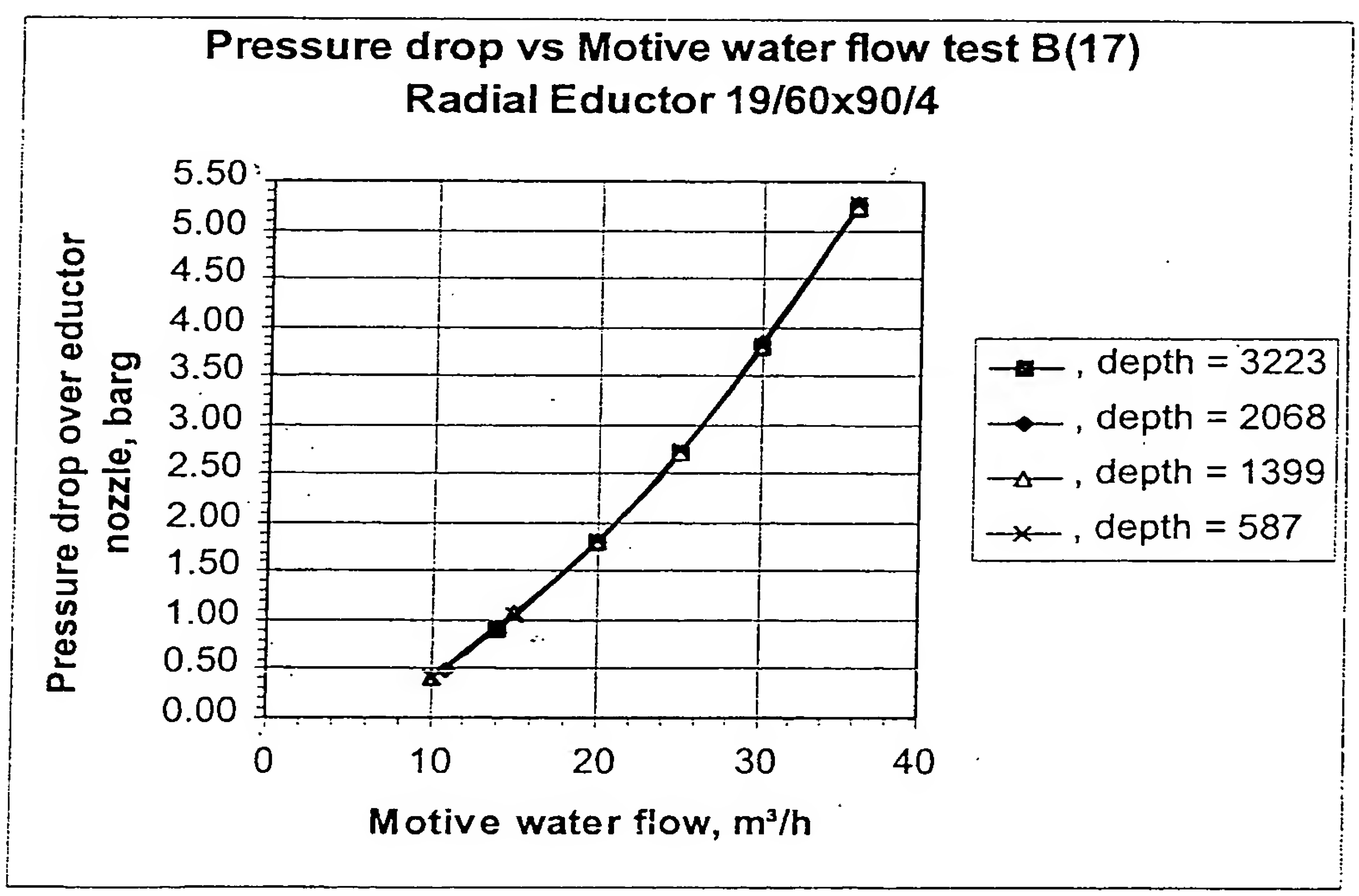
Pressure drop vs Motive water flow test B(17)
Radial Eductor 19/60x90/4
Pressure drop over eductor nozzle, barg
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
10
20
30
40
Motive water flow, m³/h
, depth = 3223
, depth = 2068
, depth = 1399
, depth = 587

FIG. 6

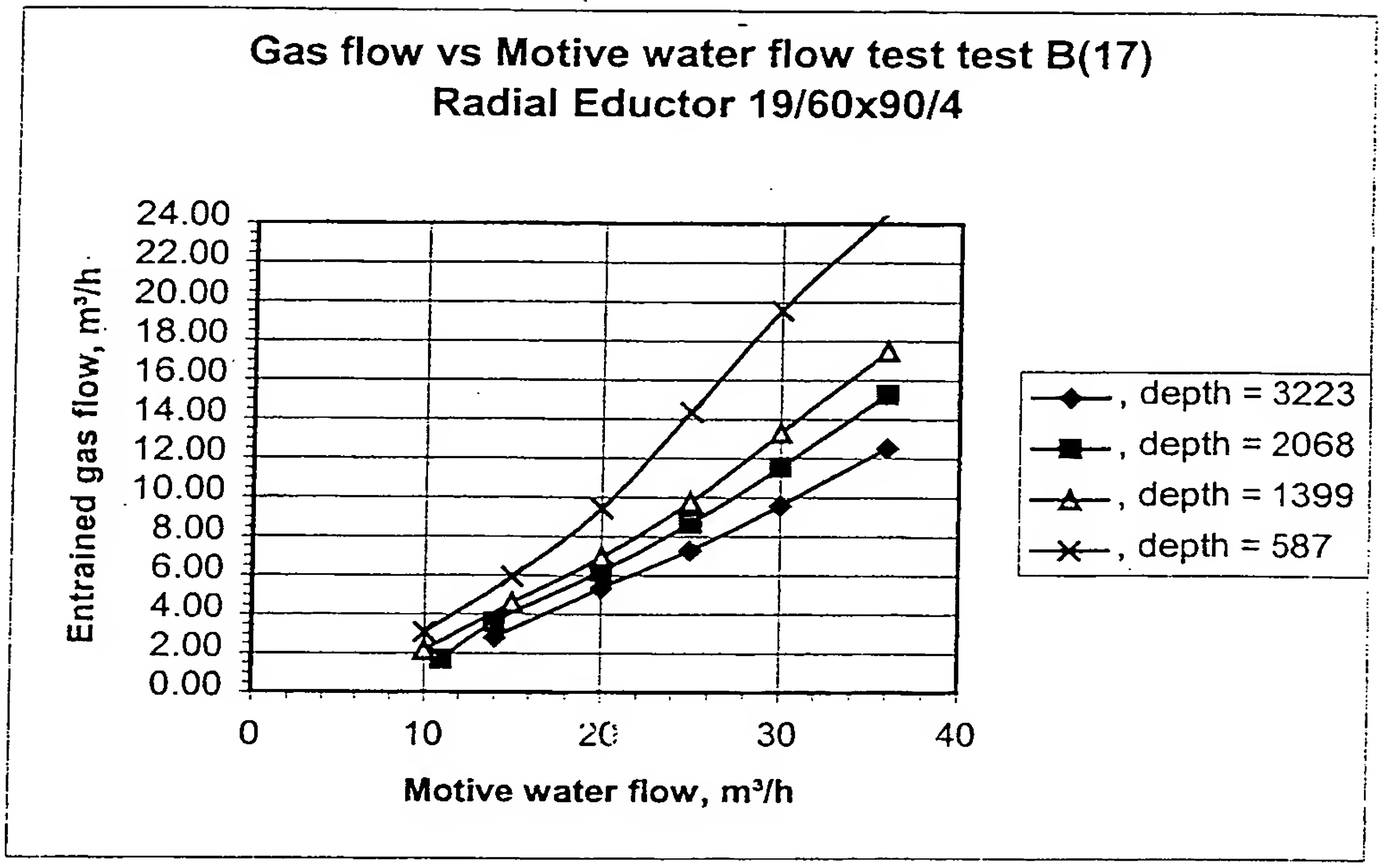
Gas flow vs Motive water flow test test B(17)
Radial Eductor 19/60x90/4
Entrained gas flow, m³/h
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
10
20
30
40
Motive water flow, m³/h
, depth = 3223
, depth = 2068
, depth = 1399
, depth = 587

FIG. 7

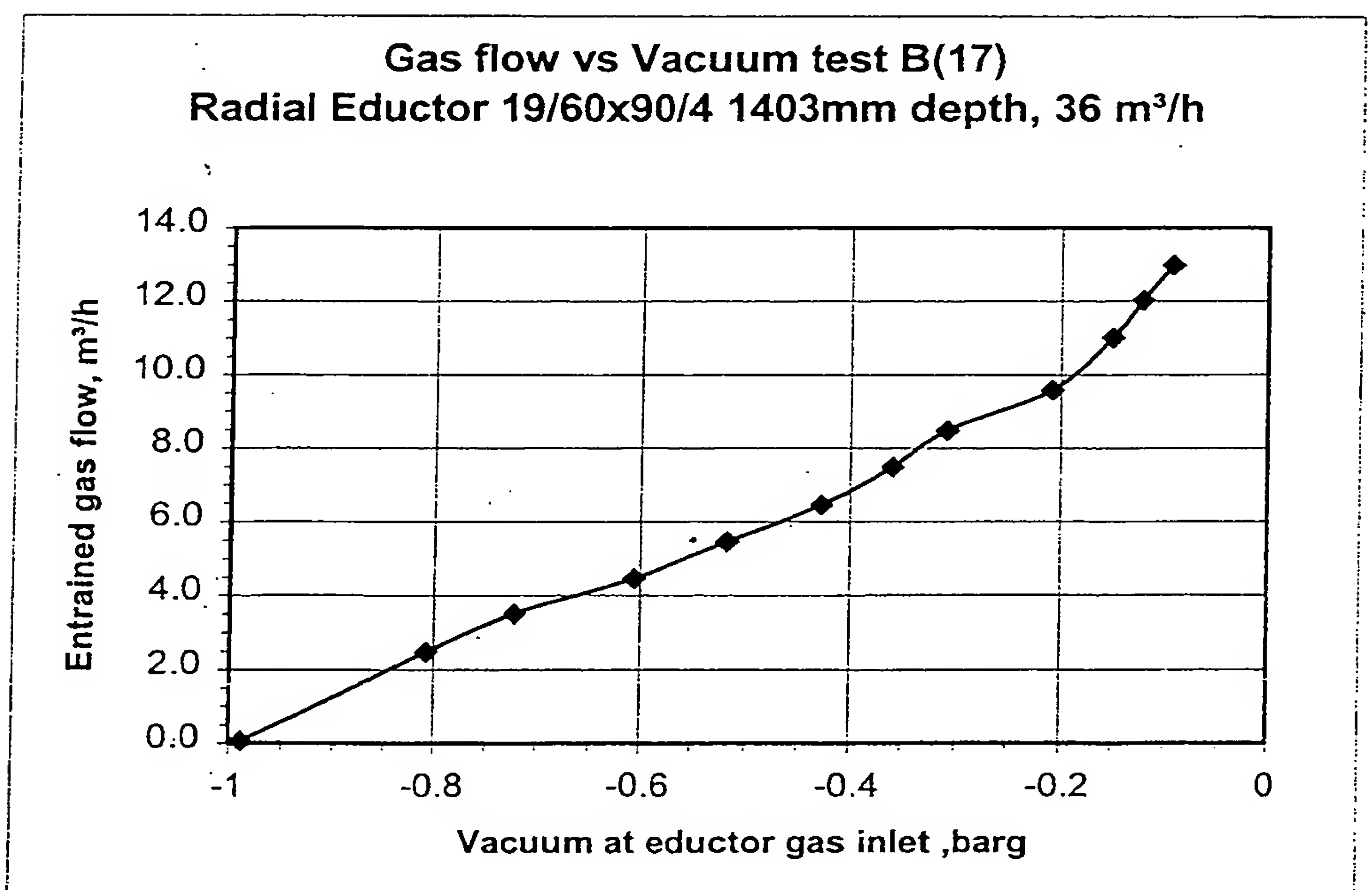
Gas flow vs Vacuum test B(17)
Radial Eductor 19/60x90/4 1403mm depth, 36 m³/h
Entrained gas flow, m³/h
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-1
-0.8
-0.6
-0.4
-0.2
0
Vacuum at eductor gas inlet ,barg

FIG. 8

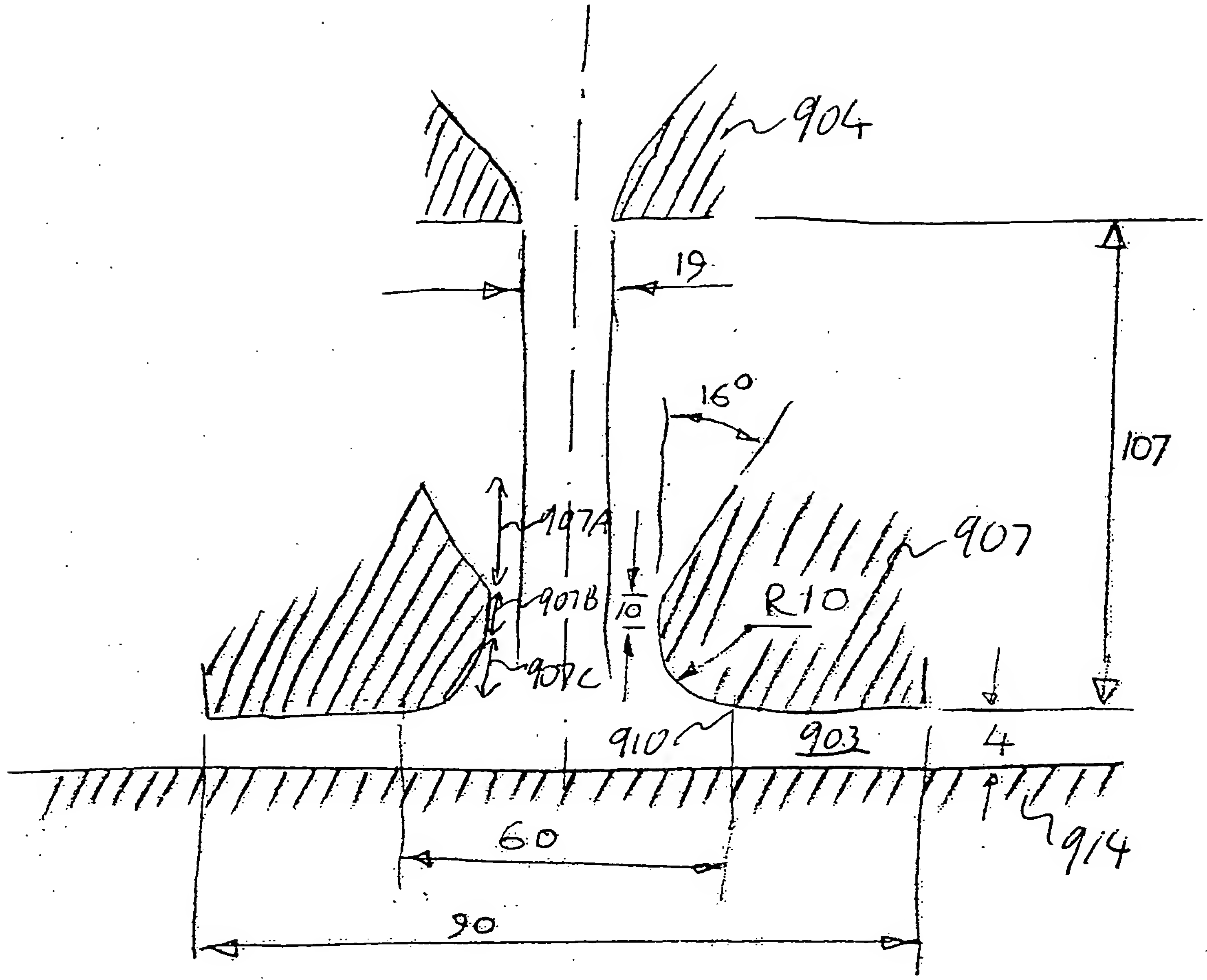
904
19
107
16°
907A
907B
907C
10
907
R10
4
910
903
914
60
90

FIG. 9

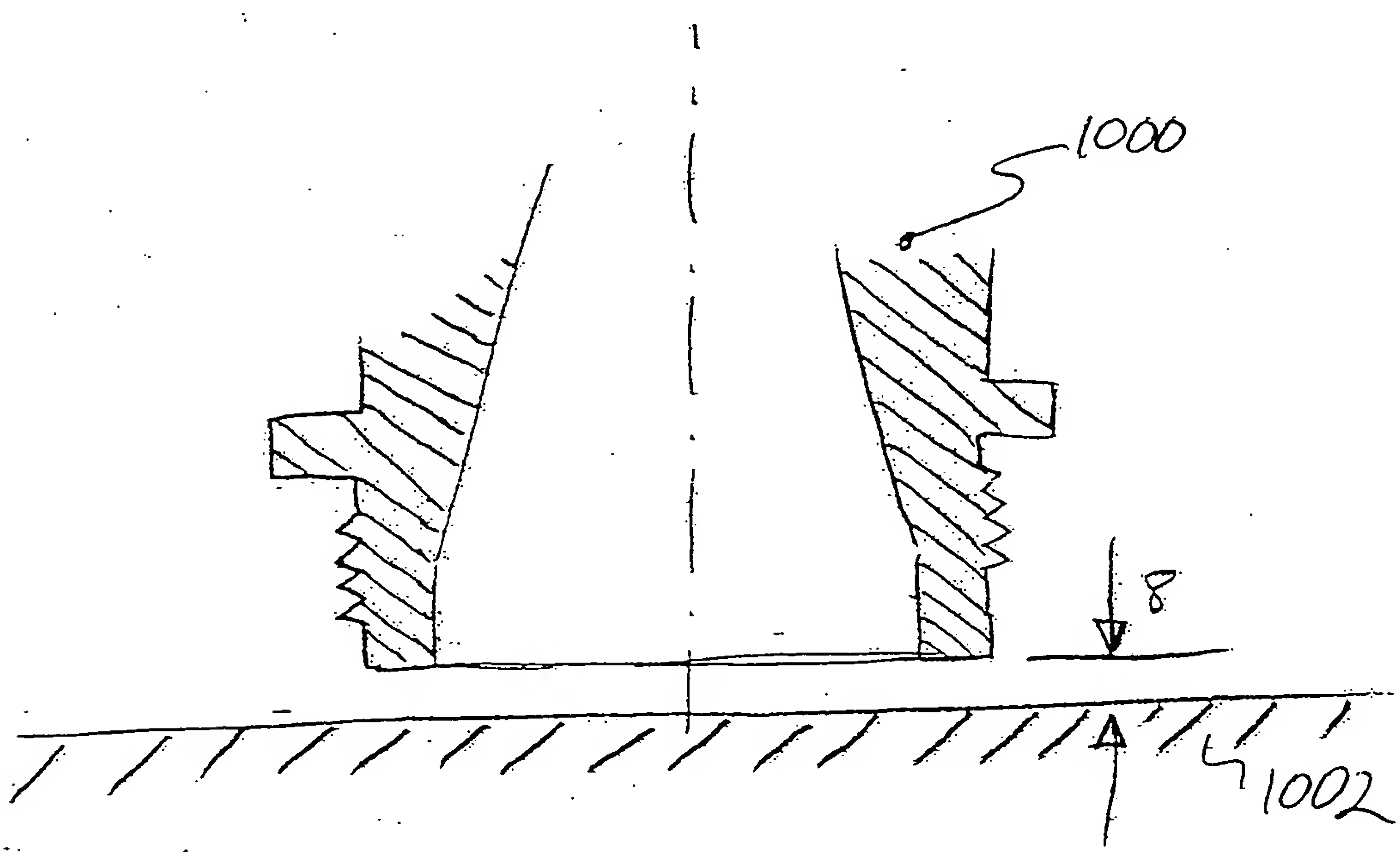
1000
8
1002

FIG. 10

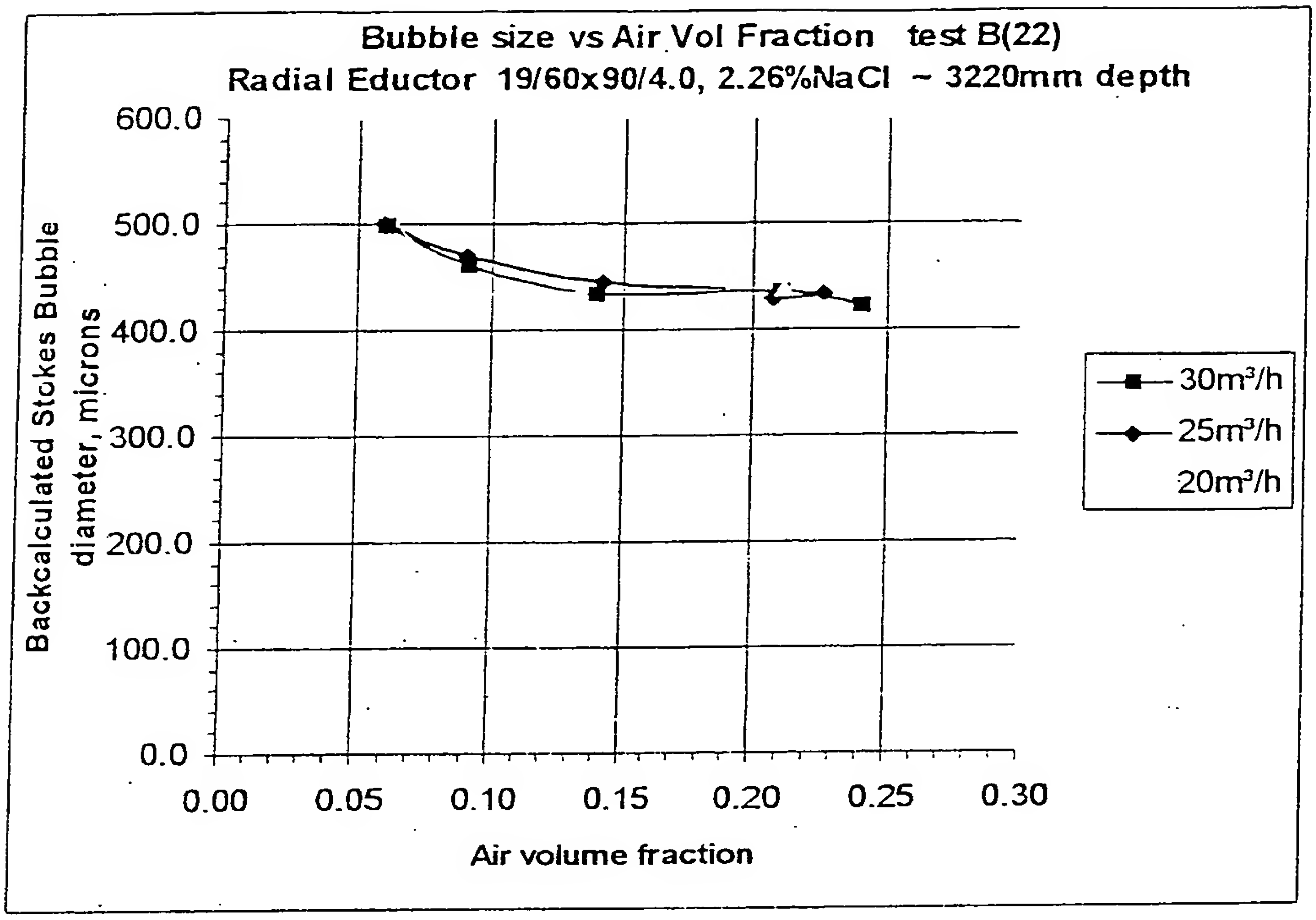
Bubble size vs Air Vol Fraction test B(22)
Radial Eductor 19/60x90/4.0, 2.26%NaCl ~ 3220mm depth
Backcalculated Stokes Bubble diameter, microns
600.0
500.0
400.0
300.0
200.0
100.0
0.0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Air volume fraction
30m³/h
25m³/h
20m³/h

FIG. 11

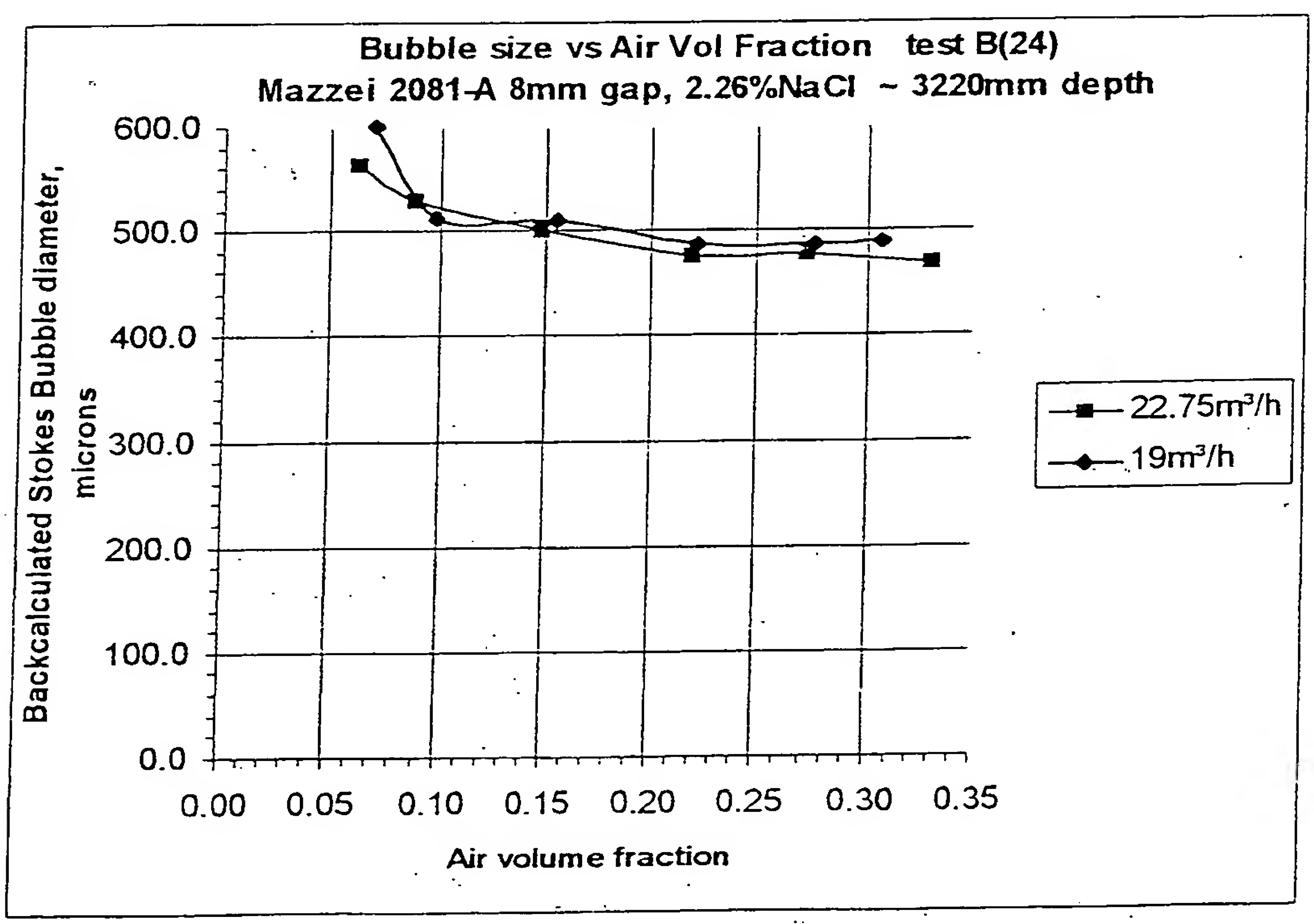
Bubble size vs Air Vol Fraction test B(24)
Mazzei 2081-A 8mm gap, 2.26%NaCl ~ 3220mm depth
Backcalculated Stokes Bubble diameter, microns
600.0
500.0
400.0
300.0
200.0
100.0
0.0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Air volume fraction
22.75m³/h
19m³/h

FIG. 12

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Young & Thompson
745 South 23rd Street
Arlington, Virginia 22202
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